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# ELECTRONICS PERSONNEL RESEARCH


DEPARTMENT OF PSYCHOLOGY

UNIVERSITY OF SOUTHERN CALIFORNIA


RESTRICTED

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# SHIPBOARD OBSERVATION OF ELECTRONICS PERSONNEL: GENERAL CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

UNIVERSITY OF SOUTHERN CALIFORNIA LOS ANGELES

JUL 1953

# PREFACE

This report is the last of a series based on shipboard observation of electronics personnel aboard ships of the destroyer class. The titles of these reports are given here along with a brief indication of the content of each. Security restrictions do not permit the general circulation of all of these reports but the accompanying list will help the reader place the present report in context.

1. Shipboard Observation of Electronics Personnel: A Description of the Research.

   A general presentation of the problem, its background, and the observational techniques which were employed.

2. Shipboard Observation of Electronics Personnel: Detailed Descriptions of Observational Techniques.

   A report for the professional worker who desires precise detail regarding the forms and instructions used and the decisions underlying their selection. The summarized data are provided in a classified supplement.

3. Shipboard Observation of Electronics Personnel: Implications for the Training of Electronics Personnel.

   Various problems of training are formulated and related to the observational data. (RESTRICTED)

4. Shipboard Observation of Electronics Personnel: Shipboard Activities of Electronics Technicians.

   Detailed accounts of the activities of electronics technicians are presented. Topics such as the materials, duties, problems, and future plans of the technicians are discussed. (RESTRICTED)

5. Shipboard Observation of Electronics Personnel: Brief Descriptions of Related Electronics Jobs.

   The jobs of the Sonarman, Radarman, and Radioman are briefly described. The areas of overlap between these jobs and the job of the ET are discussed. (RESTRICTED)

6. Shipboard Observation of Electronics Personnel: Implications for Certain Operational and Administrative Problems.

   Problems of Shipboard administration, policy, and the operational requirements of the electronics situation are related to the observational data. (RESTRICTED)

7. Shipboard Observation of Electronics Personnel: General Conclusions and Recommendations for Further Research.

The objectives of the research are reexamined and general conclusions are drawn. Promising research hypotheses and methods are presented. (RESTRICTED)

## ACKNOWLEDGMENTS

The research reported in this series reflects the contribution of a large number of persons within the Military Establishment. Grateful appreciation for this assistance is extended to the Cruiser Destroyer Force, Pacific; the Training Command, Pacific, and the Underway Training Element of that command; the Training Division and the Personnel Analysis Division, Bureau of Naval Personnel; the Personnel and Training Branch of the Psychological Services Division of the Office of Naval Research; and the Electronics Coordinator's Section of the Office of the Chief of Naval Operations.

## ABSTRACT

This report concludes a series of technical reports based upon shipboard observations of electronics personnel on ships of the destroyer type.

The objectives of the research are reexamined and the varying degrees of their attainment are evaluated. Some of the more general conclusions are presented.

The report is concluded with a number of suggestions for improvement in the electronics maintenance situation and a series of recommendations for future research.

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# SHIPBOARD OBSERVATION OF ELECTRONICS PERSONNEL: GENERAL CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH.

## I. INTRODUCTION

### Purpose

This is the seventh and last report of a series based upon observations made on ships of the destroyer type. A list of the titles of the previous reports and brief indications of their contents are given in the preface. This report presents the general conclusions derived from the research, suggestions for the improvement of the current shipboard electronics situation, and recommendations for future research within the electronics area.

### Background

The rapid development of Naval electronic devices immediately prior to and during World War II created numerous problems. During the period following this war, some of these problems were aggravated. One of the most serious was the fact that the electronic equipment was at times inoperative or functioning below its rated capacity when employment of the ship required peak electronics performance.

Research efforts were initiated within the Navy in order to identify and determine the relative contribution of the various factors involved. Since it was realized that all of the problems could not be eliminated by the improvement of equipment alone, additional research was initiated to explore the general area of shipboard personnel in an effort to determine the extent to which the behavior of human beings

was responsible for these electronics problems.

The nature of the problem necessitated a broad approach to make certain that pertinent areas would not be overlooked. In a very real sense, the "problem" was to discover and state in a testable form the problems of a personnel nature which existed. This philosophy occasioned the initiation of research whose principal mission was to obtain accurate descriptions of shipboard electronics situations as they occurred on ships of the destroyer class.

Twelve observational procedures were tried out aboard a number of destroyers, appropriately modified, and subsequently employed by teams of observers who visited twenty ships of this type. These visits varied in length from 2½ to 5½ days with an average of about four days per trip. The observations occurred while the ships were engaged in training operations at sea. These operations were of the usual type and included almost all of the different destroyer missions with the exception of shore bombardment.

The observational sample consisted of 530 enlisted men and 110 officers.[1] Although it was desirable to cover the entire area of electronics, it became apparent quite early in the planning of the study that certain concessions had to be made to reduce the domain to a workable size. It did not appear feasible to make a complete and comprehensive description of both the operating and maintenance aspects of

[1] The sample of enlisted men consisted of Electronics Technicians, Sonarmen, Radarmen, Radiomen, and Fire Control Technicians. The officer group was made up of Electronics Material Officers, CIC, ASW, Communications, Operations, Gunnery, Engineering, and Executive Officers.

electronics activities. As a result, the attention of this study was focused on maintenance.

The shipboard observation program was developed in an effort to achieve a number of general objectives. Perhaps the most important of these (in the sense that the observational methods were primarily designed to accomplish it) was the objective of obtaining accurate and detailed descriptions of the electronics maintenance situation as it existed aboard ships of the destroyer type. It was felt that objective descriptions would furnish factual data with reference to electronics functions which would be useful in many ways.

A second objective of the shipboard observations was to provide preliminary answers to some of the specific problems which were known to exist in the fleet at that time. Generally speaking, these answers were to be obtained by determining the consensus of the people in the fleet who were most intimately associated with the problem. A further objective was to formulate the problems in the electronics maintenance domain in such a manner that more precise subsequent investigations could be directed toward more definite answers. The research also sought to foster the development of new hypotheses based upon actual shipboard experience.

Other objectives were of a somewhat more practical nature. They had to do with such things as the establishing of research priorities, determining the feasibility of suggested subsequent research, and the development of observational techniques. A final objective of the shipboard observations was to indoctrinate thoroughly the research personnel in the problems of shipboard electronics maintenance so

that they would be better able to recognize and appreciate such problems as were later recognized.

The extent to which the objectives of the present research were met was generally satisfactory. Voluminous descriptions were obtained concerning the shipboard electronics situation. For example, the following descriptions of the electronic technician and his job were obtained:

(1) Biographical information which covered the pertinent elements of the man's background and training with respect to his current duties;

(2) A temporal breakdown of each man's duties under various shipboard conditions;

(3) Information concerning the publications, tools, and electronic test equipment employed in the performance of the job;

(4) Details of the responsibilities that each man has for the materials with which he works and descriptions of the records which are kept as a part of the job;

(5) Eye-witness accounts of the procedures employed by the man in trouble shooting situations;

(6) A record of the electronic repairs which took place during the time that observers were stationed aboard ship;

(7) Information regarding the physical conditions of the man's employment such as the presence or absence of an electronics workshop, and the accessibility of electronic equipment and spare parts;

(8) Shipboard training, its nature and frequency;

(9) A detailed account of incidents from the man's past exper-

ience which contributed to some facet of an electronics maintenance situation;

(10) Information regarding the particular ways in which the duties and tasks of various electronics rates and ratings overlap;

(11) Detailed descriptions of the job activities of each electronics technician along with an indication of the frequency with which these tasks were performed.

Similar, although somewhat less comprehensive, coverage was made of the radarmen, radiomen, sonarmen, and fire controlmen. The accuracy and detail of these descriptions provide a valuable source of information for the solution of problems which arise from time to time and which require factual information in order to be resolved. Answers to many existing questions may be derived. An examination of the data may very well provide information regarding the extent to which a particular factor occurs. If it is found that the element in question happens infrequently, it may then be inferred that this factor is unlikely to play a major role in the problem under consideration. On the other hand, were the data to indicate the occurrence of this condition to an appreciable degree, a more intensive search for specific relationships between the factor and the problem would certainly be warranted.

The extent to which the remaining objectives have been met may be judged by referring to the third section of this report which presents suggestions for further research.

## II. GENERAL CONCLUSIONS

A list of conclusions derived from the research is presented in this section. No effort has been made to order these conclusions according to their importance. To conserve space, only those of a rather general nature are included in the list. More specific conclusions and substantiation for those presented below are to be found in the preceding reports of this series and will not be repeated here.

1. A significant number of electronics maintenance problems which occur are primarily the result of the behavior of people who use and/or maintain the electronic equipment aboard ship.

2. While improvements in equipment design have tended to simplify the jobs of some electronics personnel, there is reason to believe that many, if not all, of the personnel problems have existed and will continue to exist regardless of the specific design of the equipment. These problems must necessarily be dealt with from a personnel standpoint.

3. Effective electronics maintenance aboard ships of the destroyer type depends to a large extent upon the electronics technicians. But, effective electronics maintenance cannot be achieved by their efforts alone.

4. The most important single individual in the electronics maintenance picture is the leading electronics technician.

5. There is an insufficient number of high rated electronics technicians to fill the key positions of lead ET and as a result the job is being held by lower rated men who, in many cases, lack the necessary experience to most effectively organize their group.

6. There is considerable variation among ships with regard to the number of adequately trained and experienced electronics maintenance personnel.

7. There is evidence to suggest that strict adherence to rate/rating structures may at times interfere with the application of the team concept of efficient ship's organization.

8. Active interest in electronics is a necessary but not a sufficient condition for successful performance as an electronics technician.

9. Jobs associated with the operation and maintenance of military electronic equipment must be simplified so that they can be handled by men of average intelligence with normal abilities.

10. There is a definite need for the development of realistic minimum job requirements for electronics personnel.

11. Individual tutoring and apprentice-type training techniques appear to be well adapted for training in electronics maintenance aboard ship. These techniques seem better suited for this purpose than traditional classroom procedures.

12. There is evidence to support the conclusion that the full potential of apprentice-type shipboard training of electronic maintenance on ships of the destroyer class has not been fully exploited.

13. An electronics technician's activities during the three-month period following his graduation from Class A school play an important part in his subsequent attitudinal structure.

14. There is an indication that petty officers may require additional training in order to maximize their potentiality as on-the-job instructors.

15. Shipboard training in electronics maintenance varies a great deal with the size of the ET complement.

16. Because of the great variety of types of electronic equipment, and in light of the obsolescence rate of such equipment, it is important that the training of electronics technicians permit a maximum amount of transfer to new equipment.

17. Printed materials are prime aids in the accomplishment of routine repairs as well as in the solution of novel maintenance problems.

18. The ability to read and to understand schematic diagrams of electronic circuits is one of the most important skills required of an electronics maintenance man.

19. Evidence indicates that an appreciable amount of time is spent in the preparation of maintenance records but the records do not usually reflect the current maintenance situation.

20. The trouble shooting procedures used by ETs vary widely from man to man.

21. A high priority should be given to the development of on-the-job electronics performance criteria.

22. Eighty-seven per cent of the electronics technicians indicated that they would leave the service at the end of their current enlistment.

23. It appears that influences outside the Navy are at least as responsible for the high rate of ET turnover as are factors within the Navy.

24. The ET Class A school graduate needs considerable practical shipboard experience before he is able to do his share of the electronics maintenance.

25. There is very little support for the notion that one ET ought to be trained solely for the purpose of performing preventive maintenance.

26. In the light of the high turnover rate of electronics personnel, it appears that it may be necessary to devise a maintenance program which can be carried out by men serving only one enlistment period.

27. The electronics training program within the navy must be geared to persons who have had little or no previous exposure to the field of electronics.

28. Examination of the observational data yields no basis for radical changes in the job structure related to the maintenance of electronic equipment.

29. There is evidence to suggest that potential ETs would profit from a 3 to 6 months tour of duty at sea prior to their formal Class A training.

30. The extent to which ETs participate in the maintenance of fire control radar and sonar equipment is primarily dependent upon the availability of trained men in those ratings. Ships having an adequate number of trained sonarmen and fire controlmen make few demands upon the ETs' time for sonar or fire control radar repair.

31. The majority of observed repair instances involved communications equipment.

32. The most common cause of equipment malfunction within the present sample was failure of electronic tubes.

33. The maintenance activities of the ETs do not strictly correspond to their pay grades.

34. The tools and test equipment furnished the electronics technician are of satisfactory quality but, in some instances, are in short supply.

35. There is little evidence of duplication of effort due to overlap between duty assignments of the electronics ratings.

36. Electronic maintenance is most effective on those ships where definite and specific maintenance tasks are assigned to individuals.

37. The job of the ET and the job of that fire controlman who is responsible for the upkeep of the electronic fire control systems are essentially similar.

38. There is evidence to indicate that the electronic maintenance activities of the sonarmen are not shared equally by all members of the sonar group.

39. On ships of the destroyer class there is little evidence of specialization of function among members of the ET group.

40. On ships of the type studied, radarmen and radiomen seldom attempt repairs which require any test instrument other than a tube tester.

41. None of the electronics ratings indicate that they spend as much of their time engaging in preventive maintenance activities as their cognizant officers think that they should spend.

42. There is considerable ship to ship variation with regard to the amount of preventive maintenance of electronic equipment.

43. There is considerable ship to ship variation in the division of responsibility for preventive maintenance of electronic equipment.

44. Evidence indicates that preventive maintenance is the key to effective maintenance of shipboard electronic equipment.

45. A list of factors contributing to unsuccessful corrective maintenance showed that the most common weakness was a failure to make adequate visual checks early in trouble shooting.

46. Generally speaking, the job of electronics material officer is being filled by men whose past experience and training qualify them for this duty.

47. The shift of the administrative control of the electronics technician from the engineering department to the operations department is generally approved by all concerned.

48. The sonarmen have a great deal in common with both the ET and FC (FT) but generally appear to be less concerned with maintenance than either of these two ratings.

49. There is little evidence of interdepartmental friction with regard to electronics maintenance matters.

50. Generally speaking, ETs do not spend an inordinately large percentage of their time on non-electronic duties.

It is important that the reader's attention be called to certain limitations which exist with respect to the generality of the information from which these conclusions are derived. The fact that this information is the result of observations made only during training exercises aboard ships of only one type and in only one geographic location must constantly be kept in mind. Additional restrictions which deal with methodological considerations pertinent to an interpretation of the data are elaborated upon in Report No. 2 of this series.

This series of reports and the conclusions presented herewith are considered by the authors to accurately describe the electronics maintenance situations aboard the particular sample of ships that was visited. However, no claim is made that these descriptions or conclusions are

generally applicable to other types of ships in other locations under other circumstances. It certainly would be a case of generalizing far beyond the limits of the sample to consider these conclusions to be applicable to the Navy as a whole.

## III. RECOMMENDATIONS FOR FUTURE RESEARCH

Throughout the conduct of this work and the analysis of the data, numerous areas of possible improvement in electronics maintenance were observed. Because it is one of the goals of this research effort to look ahead toward a continually improving performance level within the fleet, some of the questions will be discussed here along with suggestions for research approaches to their further development.

### Job Requirements

During a period of national emergency, all of the armed services, industry, and government compete for the top ten per cent of the available manpower. Since the manpower demand during national emergencies always exceeds the available supply (particularly in the case of the top ten per cent), the armed services are frequently forced to make do with fewer high level recruits than they would desire. They find it necessary to do the job with men of average intelligence and normal abilities. For this reason, it is essential that the services examine their various billets to determine what the minimum requirements are for each. The question is: "How little of ability X is needed to successfully master and perform the duties of billet Y ?"

Various research efforts may be brought to bear upon such questions. A traditional approach to the problem is to have "experts" who are quite familiar with the job make judgments as to the minimum amount of various abilities which are required in order to satisfactorily perform on the job.

Another approach would be to allow a group of men who did not meet the present requirements in some specified way (e.g., a group of men who had slightly below the required GCT level for a given job) enter into the usual training channels and go out on the job along with a group of men who did fulfill the requirements in every way.

Ideally, this experimental group would not be told that it was below the GCT standard and, if at all possible, this information would not be made available to the schools or to the ship to which these men were subsequently assigned. Assuming some adequate measure of job proficiency, it would be possible to follow up this experimental group of men and compare their school grades and shipboard performance with those of a comparable group which had met all of the standards and which had received its training at the same time under similar circumstances and had been assigned to similar ships.

This experimental procedure might permit a gradual relaxation of some of the standards which currently limit the available manpower for certain highly technical jobs such as that of the electronics technicians. This method of revising the standards would not involve any great risk of training time or money because, in every case, the experimental group selected would be representative of recruits who were just barely below some existing standard.

## Methods of Fleet Training

Evidence collected in this study suggests that there is a real need for experimental study of methods of training electronics maintenance personnel aboard ship. It was shown in Report No. 3 of this series that individual tutoring and apprentice-type training are well adapted to fleet needs. There is considerable evidence, however, that most of the concepts of fleet training are patterned after principles of classroom or formalized training rather than on-the-job training. This suggests a need for careful study of on-the-job training methods as they might be applied in a practical situation on ships of the destroyer class.

Some of the most straightforward questions that should be answered include the following: What are the unique characteristics of the transition which a newly trained Class A school graduate is required to make when he is first assigned to operational duty? Evidence collected here stressed the importance of this period in the course of a man's development, particularly with regard to his interest to learn and his willingness to benefit from training. These characteristics are markedly affected by the course of events during this period. Special attention should be given, therefore, to evaluating this transition from formalized classroom instruction to learning while on the job.

Factors which might contribute to an understanding of this problem range from the effects of fleet experience prior to Class A training to more directly related possibilities such as carefully organized transition training in the form of practical experience

with a highly trained crew before assignment to a semi-independent post on a ship.

It would appear important to determine the significant variables in producing successful individual tutoring by experienced men. That is, are there training principles that can be demonstrated to be superior in this situation, and is it possible to train the more experienced men to be better on-the-job instructors?

It appears that the fleet training situation in electronics maintenance varies a great deal with the size of the ET complement aboard. With reference to the destroyer class, there is ample evidence to support the conclusion that the full potentials of apprentice-type training have not been explored.

At the present time, many rudimentary questions do not appear to be clearly answered in the minds of the supervising technicians. For example, is it better to give guidance freely to a new man aboard a ship and to help him very much through his first repair efforts or is this likely to build up an undesirable dependency such that the junior man is never able to cope with problems on his own? Is it better to let the man discover the knack of it for himself? Are training aids and reference materials designed for maximal effectiveness for the individual at the fleet level or are they better adapted to some form of group instruction?

Careful study may be made of the various alternative solutions to the fleet maintenance training problem. This has implications not only for maximizing the extent to which Class A school graduates use their training, but also shows promise for developing adequate personnel

through training on the job in cases of necessity.

## Learning to Maintain New Equipment

Because of the great variety of electronics instruments necessary for different operational conditions and the continuous development of more advanced circuits, there exists an urgent need for technicians who are able to transfer their skills to new situations. In the language of human learning studies, this is a problem of transfer of training. What form must a man's training take to permit a maximum amount of transfer from equipment to equipment?

This question is much more easily asked than answered because it includes many of the important sub-problems of training. For example, should all electronics technicians be "junior engineers" in the sense of being well trained in electronics theory and the fundamentals of electronics design? A related question concerns the possibility of more carefully defining the essential differences between the typical engineering approach to electronics and the typical technician's approach to electronics. If characteristics unique to electronics repair behavior can be identified, certain problems such as how much theory and what specific maintenance matters should be taught to ETs may better be answered.

Still other possibilities involve the division of maintenance tasks along qualitative lines and the development of some men at a much higher level of comprehension than the majority. Most of the routine maintenance tasks would then be accomplished by personnel

in whom the training investment is small.

In an effort to better understand the transfer characteristics of maintenance behavior, it would appear to be very desirable to set up a study to observe the behavior of experienced men who are trying to master an unfamiliar piece of gear. With an empirically conducted study, it may be possible to define accurately what the limits of self-instruction are in this situation. If it can thus be determined exactly where the man is unable to cope with the new situation by himself, it may be possible to predict the type of technique or the nature of the aid needed to overcome the limitation. Many of these questions should be straightforward and easy to test.

When a ship receives new gear, the ET typically has to rely heavily on the equipment instruction book to introduce the instrument to him. Detailed observations of the way in which this all-important reference is used by different men when compared with the success that the men have with the equipment should provide evaluation information on the reference material and on the extent to which the men are able to use it. The observational data showed rather conclusively that reference materials play a crucial role in coping with novel situations.[2]

It is desirable to determine to just what extent technicians are able to use BuShips' manuals. It is possible that more training in their use is needed or that the manuals lack certain essential features which could readily be added. A study of this sort would provide a

[2] There are repeated indications in the data of the importance of certain auxiliary publications (such as Electron) to training in the fleet.

basis for the determination of the feasibility of developing a set of reference books specifically for the use of electronics maintenance personnel aboard ship.

## Reading Circuit Diagrams

Throughout the observational data, there was a recurring emphasis upon the importance of the ability to read schematic diagrams. Since this is a symbolic process somewhat unique to the electronics field, and since it involves forms of concept formation which are not usually taught directly, it suggests that a better understanding of the processes involved in reading and using schematic diagrams be sought.

Many questions should be evaluated. When ETs finish school, are they able to use schematic diagrams effectively? If not, is it possible to determine why? Should specific attention be given to training the student in the reading of schematic diagrams, or will the student pick it up on his own?

Assume that it is desired to teach students how to use schematic diagrams - is it known how best to go about this training? Is it better to work from simplified models with only the essential circuits and components shown and only later progress to complete forms which include auxiliary circuits and all the components? Is it better to progress from a stage by stage analysis to a section analysis or is it better to begin with large units and work backwards? Is a stage an adequate unit for such symbolic instruction or should concentration be placed on circuits within the stage, as for example, beginning

with rudimentary plate, grid, filament, and screen circuits and tracing current flow?

Should a difference be made between degrees of concentration upon learning to read schematics by visualization aids (e.g., studying wave forms at test points) and learning by more general concepts of current flow? What, if any, is the value of introducing "equivalent resistance" analysis of the circuit in training men to read diagrams?

The questions indicated above represent a sample of the items of information which have direct bearing on the training of men to use circuit diagrams. Only to the extent that such questions can be answered with facts can general improvement be made in the use of schematic diagrams by electronics technicians.

## Organization

There is considerable variation among ships with regard to the number of adequately trained and experienced electronics maintenance personnel. One department or division may be operating at full strength while another is seriously undermanned. It seems unlikely that all of these ships would be able to follow exactly the same detailed practices with regard to electronics maintenance. The ships' commanders are faced with the very real problem of getting along with what they have.

There are some suggestions in the data that strict adherence to rate/rating structures may interfere with the application of the concept of most effectively organizing a crew into a fighting team whose weapon is the ship. Research efforts could be profitably expended to explore the feasibility of revising present rate/rating structures and

schedules to permit a more flexible system for assigning men to ships and employing them once they are aboard.

## Sea Duty Prior to Class A School

At the present time, many of the electronics technicians are sent directly from boot camp to Class A school. While the reason for this procedure was generally understood, most of the members of the shipboard sample believed that there were certain benefits to be derived from a period of sea duty prior to formal schooling. The consensus was that a three to six months tour of duty at sea would serve to orient the man with regard to the Navy, life aboard ship, and general features of shipboard electronic equipment. As a result, when the men were assigned to school, they would be better able and more highly motivated to take advantage of the training that was offered them. Experimental tryouts of this scheme would provide the basis for an empirical evaluation.[3]

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[3] One system has been suggested which would, in essence, send the recruit from boot camp directly to active sea duty for a period of three to six months as a striker in one of the electronics ratings. At the completion of this first period of sea duty, he would be returned to school where he would be taught basic electronic maintenance fundamentals. At the completion of an abbreviated school training period, he would be sent to the fleet as a potential third class petty officer with the understanding that he would receive further school training before advancing to second class petty officer. In addition, he could be channeled into any one of the several allied electronics maintenance ratings at any time prior to this second training period.

Present evidence does not permit an evaluation of this training scheme, but it is entirely possible to make such training systems the subject of future research.

## Development of Selective Devices

One of the most plentiful classes of information which can be secured from the observational data concerns job requirements interpreted as generalized abilities and as specific performance characteristics. It would appear that such information could be utilized to develop an experimental battery of predictors of electronics technicians' success. A battery is suggested because of the complexity of the determiners of success. Characteristics associated with foresight and planning were noted in Report No. 4 of this series and certain fundamental skills (arithmetic, etc.) have been shown to be relevant.

## The Importance of an Interest in Electronics

Another factor which was observed to be of extreme importance to successful performance as an electronics technician is an active interest in electronics. The motivating state of affairs which is involved is quite like some of those seen in educational guidance situations. In these latter instances, interest measuring devices have been constructed and have been shown to be very useful. This implies the possibility of determining a man's interest in electronics and related fields before his training is begun. Then, either persons with strong interests could be selected for the training or special efforts could be made to build up interest and to improve motivational factors during training.

In light of these facts, it appears to be worthwhile to develop an interest measure as a selective device for work in electronics.

## Paper Work

The domain of electronics maintenance in the Navy has associated

with it paper work which is intended to report the details of the maintenance activities of the group, the use of spare parts, and includes the general procedures involved in the process of ordering and maintaining adequate stock records of the electronics spare parts. Despite the expenditure of an appreciable amount of time in the preparation of these records by technical personnel, the records usually do not accurately reflect the current state of maintenance affairs.

The entire problem of maintenance paper work presents itself as an appropriate subject for continued research in an effort to minimize the paper burden. A study of this type should take into account the attitude of the men toward records and possible means for instilling appropriate attitudes during early stages of technical training.

## The Role of Logical Analysis in Trouble Shooting

The descriptions of trouble shooting obtained in the course of this research indicate that there is no one set procedure used by all electronics technicians under all circumstances. However, the various trouble shooting procedures each have staunch advocates. An experimental determination of the efficacy of the several procedures appears to be feasible and would provide answers to such questions as - is there one best way to trouble shoot?

Some experiments might be based upon the importance of logical analysis as a first step in the trouble shooting process. Advocates of this procedure insist that relatively detailed analysis of front

panel information should be made before any internal tests are attempted.[4]

One way to test this possibility experimentally would be to train two groups of recruits differently in the laboratory phases of their work. For one group, a conventional approach would be used. In the other group, the students would be required to make a complete and logical written analysis of the situation and a list of hypothetical causes before they would be allowed to open up a chassis. Both groups would then be introduced into a new situation and performance criteria of time, errors, etc., could be employed to compare the relative group effectiveness. Variations of the above involve the instruction of technicians on principles of logical analysis which would be supportive of the front panel approach.

## Problem Solving Research

The process of trouble shooting electronics equipment is a specific example of the general class of behavior known as problem solving. There is potentially much to be gained by observing this problem solving behavior under carefully controlled conditions and endeavoring thereby to develop an organized set of principles to explain the trouble shooting process.

There are many ways that such research might proceed. It would be possible to determine what types of analytical behavior processes are

[4] Some evidence in support of this point of view can be seen by examining the data in Report No. 4 of this series in which a large number of incidents were observed where minor difficulties (which could have been detected without opening up the set) were overlooked.

involved in present day trouble shooting. Do all good technicians use the same problem solving techniques? If they do not, what can be learned about the differences in the techniques used by good and by poor trouble shooters?

It is desirable to identify the behavior variables in electronics problem solving behavior. If they can be determined, can they be defined operationally, quantified, and used experimentally? If this can be done, it then becomes important to relate these variables to the task of training people to trouble shoot. In other words, can we learn exactly what to train, how much emphasis to give certain processes, and what relation one variable should have to another?

One way to start the formulation of this problem would be to collect detailed empirical records of how men do trouble shooting. This possibility appeared so strong that it has already been undertaken to a certain extent by this research group. A standardized piece of apparatus into which standardized faults can be placed is being used. Complete detailed records are being kept on twelve repairs made by each of approximately 36 Navy ETs with varying degrees of experience.

Records being collected include every point tested, and every test made is described in temporal order with a complete record of time spent on each. Because the equipment and the malfunctions are standardized, it is possible to compare these records of behavior in terms of patterns and sequences of response as well as the number of incorrect hypotheses, number of reversals in reasoning, total number of tests made, and the like. A detailed report on the outcome of

these studies will be made at a later date.

Still another possibility for evaluating the trouble shooting process exists in comparing these detailed records of Navy technicians repairing standardized circuits with records obtained in industrial situations and in commercial trade schools. The industrial situation is unique, however, in that it has complete freedom in organizing its maintenance program around personnel who can be anticipated to remain employed indefinitely and in whom different training investments can either be made on the job or required of applicants for the job. There is evidence that industrial maintenance proceedings will provide numerous clues to improving in-service electronics maintenance.

## Technological Changes

Considerable research will be needed to keep abreast of basic changes in electronics technology. This is particularly true in terms of the way that these changes affect manpower resources. It has become necessary to try to predict, in advance of the development of any instruments, the effects which such instruments have on personnel requirements. It is necessary to predict job performance requirements of newly developed electronic systems before these systems are in use. This procedure is as applicable to maintenance behavior needs as it is to operational behavior needs.

Data presented in an earlier report pointed out some of the equipment limitations upon repair. Most of these involved design considerations with recent developments in the field of human engineering. Greater attention has been paid to the designing of equipment for optimum maintenance. There is evidence in the data that considerable room

for improvement still exists. A reexamination of Table 34 in Report No. 4 of this series suggests that specific idiosyncrasies of individual models can be readily determined empirically. The collection of this information in an extended sample of operational conditions would greatly supplement information which can be estimated while equipment is in the drawing board stage.

If such work has not already been started, it would appear desirable to collect in the form of a design engineer's guide those facts which can be empirically demonstrated as affecting maintenance operation. Preliminary information collected in connection with this study suggests that the number of these factors that are relevant are quite numerous.

## Equipment Operational Characteristics

In a manner coordinate with that above, the basic operational characteristics of different electronic instruments under normal operating conditions should be observed. These observations would include a record of equipment malfunctions and the circumstances under which they occurred. Apparently this type of information has been secured in the past chiefly through repair forms completed by men in the field and forwarded to the Bureau of Ships.

An empirical series of observations could be made to serve as a check on the proportion of the equipment malfunctions actually reported. Direct empirical observations of equipment behavior would also permit the collection of information which was not included in the current records. This kind of an empirical observa-

tion of equipment characteristics has implications for training development by providing knowledge of the relative frequency and severity of the actual malfunctions which occur.

Methodological Studies

A number of different observational techniques were employed in the course of the research. The concurrent use of several techniques permits judgments of their relative merit. Among those used in this study, the Card Sort technique appears to offer most promising potentialities for comprehensive, detailed descriptions of job activities, and appears to merit further research to find out more about the technique itself.

The reader will recall that this technique consisted of a man sorting a large number of cards bearing detailed statements descriptive of electronics maintenance tasks. The man selected those statements descriptive of his job and then sorted these cards in accordance with such criteria as frequency of performance on the job and the amount of skill and knowledge involved. The first use of this method reveals that subjects are both willing and able to deal with a fairly large number of cards and are also willing to continue sorting for a rather long period of time without taking a break.[5] Subject interest was rather easily stimulated and held at a relatively high level.

Despite the good showing of the card sort method, it still requires considerable methodological work. Additional research is planned

[5] There are 245 cards in the deck and it usually required more than an hour to complete the sorting sequence.

to explore the effects of other means of administering the method and, perhaps more importantly, to assess such formal characteristics of the instrument as its reliability and validity under various conditions.

Frequent mention has been made throughout this report of the desirability of assessing the ability requirements of the various billets. Since people are known to differ with respect to abilities, it is important to find out the extent to which the various jobs call upon the use of these abilities. In this way, it is possible to place the man in the billet which will take advantage of his ability strong points and not require the use of certain abilities in which he is weak. A preliminary attempt to explore the ability requirement area was made in the course of the present investigation. On the basis of information thus obtained, it is currently planned to make extensive revisions of the procedures employed.

A third methodological study that is planned involves the determination of the effects of administering some of the indirect information gathering techniques by mail. In the ideal case, this approach seeks to compare information gathered by on-the-spot observers with information that is obtained from the same ships by the use of indirect means. The task in this case will be to devise schemes for surveying the area and producing information which is most like that which would be obtained by shipboard observers.

## Extension of Observations

The observations which served as a basis for this series of

reports were limited to ships of the destroyer type and were focused on maintenance aspects of the electronics behavioral domain. The possibility for extending these observations into ships of other types and into the operational aspects of the behavioral domain is recognized. Future observations will employ refined versions of the observational techniques developed in the course of the maintenance study. At the present time, an indirect method of obtaining information is being developed for use within the Atlantic Fleet in order to obtain a broader coverage of the maintenance domain and to test the feasibility of collecting such information in this indirect manner.

Extensions of the observations will provide a larger and more representative sample which will permit a greater amount of generalization than is possible on the basis of the present results. It will enable one to answer such questions as: Are there differences with respect to maintenance or operational problems between the Atlantic and Pacific Fleets? If so, what is the nature of these differences and how did they develop?

## Performance Criteria

The key to successful research in training as well as in selection and classification is the criterion measure of work performed. Usually, on-the-job performance is gauged indirectly from the judgments of supervisors or associates or estimated from "school book" types of proficiency examinations. Ratings of associates and superiors are known to be influenced by many irrelevant factors, and the conventional proficiency tests often weight verbal knowledge heavily.

Because there does not exist standardized criteria for electronics maintenance performance at the fleet level at the present time, a high priority should be given to the development of such measures. It is only by being able to discriminate the good men from the poor that progress in personnel and training can be made.

It is fortunate that all services in the military establishment appear to be recognizing this need at this time. The first step, therefore, would be to coordinate the advances made by other services with those that have been made by the Navy.

Preliminary research, which was stimulated by the exploratory observations described in Technical Reports No. 1 through No. 6 of this series, is being completed at this time by this research group. It involves the comparison of various types of on-the-job proficiency measures which range from job samples to paper and pencil trouble shooting tests. At least five varieties of measures are being used currently. The results of this preliminary effort will contribute to the formalization of an applicable research problem on criterion development for naval electronics technicans. The study will be reported in Technical Report No. 10 and an experimental test of trouble shooting skill, which might be adapted to be part of a criterion measure, is described in detail in Technical Report No. 9.

In the future development of proficiency measures, emphasis will be placed upon making them practical and economical of use. They should be capable of application under conditions of normal naval operation. In some instances more restricted measures of

proficiency may be used for research purposes in validating other more practical tests or as a criterion against which to compare classification and selection procedures and in some instances to evaluate training and operational requirements.

One of the first uses to which a newly developed criterion measure could be put is an evaluation of the effectiveness of current Navy tests such as the General Classification Test, Mechanical Test, Arithmetic Test, Aptitude Test, and the Electronics Technicians Selection Test. It is particularly important to determine the extent to which successful on-the-job performance as technicians can be predicted from the scores on these tests. In addition, other classification tests such as those developed by the Navy, Army, and Air Force and known as the Common Core Tests may be evaluated.

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